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AFFDL ltr, 12 Nov 1971.

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AFFDL-TR-68-111

CHEMILUMINESCENCE AS A SIGNALLING DEVICE

J. Brennan Gisclard

FOREWORD

This report covers work performed as an in-house research effort concerning the investigation of the phenomenon of chemiluminescence for signalling purposes. The effort was conducted by the Air Force Flight Dynamics Laboratory of the Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The investigation was initiated for the Limited War effort under a special charge number 041A-77663. The chief investigator was J. Brennan Gisclard. The work commenced in September 1965 and was completed in December 1965. The manuscript was released by the author in March 1966 for publication as a technical report. Resumption of any additional exploratory work will be only upon request from an interested department or agency.

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ABSTRACT

Reliable and unique signalling devices are a military necessity and the vagaries of nocturnal operations on land and sea engender a constant search for improvements and innovations. The phenomenon of chemiluminescence has been under study as a simple, reliable means of producing a unique light that might be adaptable as a signalling device. The chemical compound commonly known as luminol remains the best producer of "cold" light. Various attempts were made to oxidize the compound using reagents that would be safe to handle and easily available for field use but would be capable of producing a visible glow. It was found that the luminol can be oxidized with any ordinary chlorine-containing bleach to produce a greenish blue light that can be made to function as a flash or continuous glow that is visible from a considerable distance. Provided water is available, the method offers a means of signalling when electrical equipment of any kind is not available or has ceased to function. The phenomenon might also be used to create bizarre effects for psychological warfare.

INTRODUCTION

The chemical, 5-amino-2,3-dihydro-1,4 phthalazinedione, commonly known as luminol, exhibits the unique property of giving off a greenish blue light when it is oxidized in an alkaline solution. The light is short lived, however, and the reaction is irreversible so that a continuous glow is emitted only while an oxidizing agent is brought in contact with unreacted luminol. The light may therefore consist of a single flash that deteriorates rapidly or a continuous glowing stream depending upon the manner in which the chemicals are mixed.

The luminescence of luminol was first studied in detail and described by Albrecht (Reference 1). The phenomenon gained the attention of Langenbeck and Ruge (Reference 2) who performed additional experiments featuring light production, and their work was followed closely by Huntress, Stanley, and Parker (Reference 3). Other publications have appeared on luminol but the authors have concerned themselves primarily with the study of the mechanism of the reaction which is beyond the scope of this report.

The data that follows describes the various ways in which luminol can be made to react with an oxidizing agent to produce a strongly visible luminescence. In selecting the test procedures consideration was given to problems that arise from the use of chemicals by nontechnical personnel, the difference between field conditions versus laboratory, the hazards involved, and the cost of the chemicals employed in the reaction.

TEST PROCEDURE

Reference to the literature cited and that of a recent publication (Reference 4) indicate that the desirable alkalinity which optimizes light production is furnished by solutions of sodium hydroxide. Accordingly, the experiments were performed in this reagent in varying concentrations but other alkaline materials were also investigated.

Basic considerations for the use of luminol in the field are the following:

1. The compounds to be made into solutions should preferably be solids for ease of packaging and transporting.

2. They should be very soluble in water and require no special mixing procedures.

3. To reduce cost and hazard to personnel they should be capable of producing the desired effect in very low concentrations.

In view of these considerations, a number of preliminary experiments were performed. These experiments consisted of: (a) Preparing an alkaline solution and dissolving the luminol in the solution, or first mixing the solid reagent and luminol together, then dissolving the mixture, and (b) Adding an oxidizing agent to the prepared alkaline solution of luminol in the dark to observe the effects. The results are shown in Table 1.

The results in Table I reveal that the most desirable effects are produced when a solution of luminol in NaOH is mixed with a dilute solution of a bleaching compound. Either 5 percent sodium hypochlorite or a prepared solution of Du-chlor can be used. The Du-chlor is preferred, however, because it is a pure white powder that is easily handled and more stable in solution. The attached photograph shows the chemiluminescent phenomenon as produced in the laboratory. The brighter glow resulted from the usual and well-known oxidation of luminol with hydrogen peroxide and potassium ferricyanide. Hydrogen peroxide is an unstable liquid, however, and requires further investigation for field use. The glow of a deeper blue was produced with solid chemicals that can be easily adapted to field use.

VISIBLE EFFECTS FOR FIELD USE

Regardless of the degree of luminescence produced by laboratory experiments, to be useful, the effect must be demonstrated under conditions approaching actual field operations. In this respect, visibility must be achieved and persist for a length of time commensurate with the function of the signalling device and its location. An arrangement was set up in which a solution of 0.1 percent luminol in 0.1 N NaOH was fed from a 500 ml bottle at a controlled rate and merged in a Y tube with a similarly contained 0.5 percent

TABLE 1

ALKALINE REAGENT	OXIDISER USED	LIGHT EFFECTS
1% Luminol in 1% K_2CO_3	Potassium Ferricyanide 1%	Barely visible
1% Luminol in 1% K_2CO_3	Sodium Hypochlorite 5%	Increased Luminescence
1% Luminol in 1N NaOH	Sodium Hypochlorite 5%	Intense Green Light
1% Luminol in 0.1N NaOH	0.5% Sodium Hypochlorite in 0.1 N NaOH	Bright Blue Glow
1% Luminol in 0.1N NaOH	Dilute Hydrogen Peroxide and Crystals of Potassium Ferricyanide	Bright Green Glow
1% Luminol in 1%K_2CO_3	Du-chlor (Sodium dichlorocyonurate) 1%	Poor Light
1% Luminol in 1N NaOH	Du-chlor, 1%	Bright Blue Glow
0.1% Luminol in 0.1N NaOH	Du-chlor 0.1%	Bright Blue Glow
0.1% Luminol in 1% Na_3PO_4	Du-chlor 0.1%	Good Luminescence

solution of sodium hypochlorite. The merging mixture flowed by gravity through a section of 1/4 inch OD clear, plastic tubing. The device was positioned on a table three feet above the floor at one end of a tunnel used for experiments in lighting effects. As the two reagents flowed together they produced a blue glow in about three feet of the tubing. It was observed that the glow was visible at a distance of 200 feet. By changing the flow rate of the luminol solution a pulsing glow was produced which was also visible at this distance.

DISCUSSION

The oxidation of luminol in an alkaline solution in the dark produces an intense blue glow that is visible at 200 feet. It would probably be visible at greater distances provided the quantities used were proportional to those used in laboratory experiments. All the reagents required to produce the glow are very soluble in water.

The chemical reaction is unique and suggests the following possibilities for application to the Limited War effort:

1. As a unique signalling device for night operations.

2. As a locating device for rescue operations when a fire or flare would be hazardous to use.

3. As a locating device for rescue at sea.

4. As an emergency landing light on air strips.

5. As a psychological weapon by virtue of the wierd and bizarre effects that can be produced.

In any area of use additional tests would have to be made depending upon the intended application, the manner in which the reagents are to be handled, and the best means of packaging and transporting the reagents for field use.

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Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Flight Dynamics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

Chemiluminescence as a Signalling Device

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report, September 1965 through December 1965

5. AUTHOR(S) (Last name, first name, initial)

GISCLARD, J. Brennan

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
August 1966	5	4

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. Special Charge No. 041A-77653 d.	9a. ORIGINATOR'S REPORT NUMBER(S) AFFDL-TR-66-111 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES This document is subject to special export controls and each transmittal to foreign nationals may be made only with prior approval of Air Force Flight Dynamics Laboratory (FDFE).

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Para 10 per AFR 310-2	Air Force Flight Dynamics Laboratory Research and Technology Division, Air Force Systems Command, WPAFB, Ohio

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	ROLE	WT	ROLE	WT	ROLE	WT
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Unique Signalling Device						
Chemiluminescent Signal						
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Psychological Warfare						
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